WILL COUNTY LAND USE DEPARTMENT

RESIDENTIAL SOLAR ARRAY PERMITTING CHECKLIST & GUIDE

58 E. Clinton St., Suite 100 • Joliet, Illinois 60432
Telephone (815) 727-8634 • Fax (815) 727-8638
https://co-will-il.smartgovcommunity.com/Public/DocumentsView

This document is intended to provide general design requirements to expedite the building permit process for residential solar energy systems. All work performed within Unincorporated Will County shall comply with the following adopted building codes and regulations:

- 2014 Will County Building Ordinance
- 2012 International Residential Code
- 2012 International Building Code
- 2011 National Electric Code
- 2012 International Mechanical Code
- 2012 International Fuel Gas Code
- 2012 International Fire Code
- 2015 International Energy Conservation Code

Our Goal: The Will County Land Use Department will attempt to process building permits for residential solar energy systems within 3 business days of receiving all correct and necessary documentation.

Section 1

The minimum requirements for residential solar arrays are summarized below:

1. The structural installation of the system meets the following criteria:
   a. the array is mounted on a code-compliant structure;
   b. an engineered mounting system is used to attach the array to the structure; and,
   c. the array has a distributed weight of less than 5 lbs/ft^2 and less than 45 lbs per attachment (unless additional information regarding roof structure reinforcement is provided and confirmed by a certified design professional—see Structural Worksheet on page 14).

2. The electrical design of the system can be described using the supplied standard electrical diagram (see page 16) and meets the following criteria:
   a. all products are listed and identified for the application (e.g. modules, inverters, source combiners, etc.);
   b. the array is composed of 4 series strings or less; and,
   c. the inverter output is 13.44 kW or less (maximum size for 70-amp breaker) and is connected on the load side of the service disconnect.

Required Information for Permit:

1. Site plan showing location of major components on the property. This drawing need not be to scale, but it should represent relative location of components at site (see example on page 15).

Simple diagram to show where the equipment is located on the property and supports for panels spread out on all rafters. For ground mounted, show setbacks.

2. Electrical diagram showing PV array configuration, wiring system, over-current protection, inverter, disconnects, required signs, and AC connection to building (see supplied Standard Electrical Diagram on page 16).
3. Specification sheets and installation manuals (if available) for all manufactured components including, but not limited to, PV modules, inverter(s), combiner box, disconnects, and mounting systems.
4. Structural Worksheet unless structure meets modern codes with a clear inspection history (see page 14 for Structural Worksheet).

Section 2

Step 1: Structural Review of PV Array Mounting System

1. Is the array to be mounted on a roof meeting modern codes with a clear inspection history? YES ☐ NO ☐

If no, due to non-compliant roof or ground mount, submit completed Structural Worksheet (see page 14).

2. Roof Information:
   a. Is the roofing type light-weight. YES ☐ NO ☐ Material ________________

   Yes = composition (asphalt shingles), metal, wood, lightweight masonry

   No = heavy masonry, slate, etc.

   If no, submit completed Structural Worksheet (see page 14). Multiple composition roof layers may be taking a portion or all of the assumed additional weight allowance found in the 5 lbs/ft^2 allowance at the end of the mounting system section.

   b. Does the roof have a single roof covering? YES ☐ NO ☐

   If no, submit completed Structural Worksheet (see page 14).

   c. Provide method and type of weatherproofing roof penetrations (e.g. flashing, caulk) _________ (must be compatible with roof material).

1. Mounting System information:
   a. Is the mounting structure an engineered product designed to mount PV modules with no more than an 18” gap beneath the module frames at any point? YES ☐ NO ☐

   If no, provide details of structural attachment certified by a design professional. Non-engineered racking systems have undefined capabilities. PV systems should only be mounted using systems that are engineered and designed for that purpose. Structural loading of a roof is more complex when modules are angled more than 18” above the roof surface. For simplicity, this process has been limited to PV arrays that are mounted parallel to the roof surface or angled with no more than an 18” gap between the module frame and the roof surface. If an installer chooses to mount the PV modules with a larger gap or if they use a mounting system of unique design, then the mounting design would require a review by a design professional.

   b. For manufactured mounting systems, fill out information on the mounting system below:
      1. Mounting system manufacturer___________________________

         Product Name and Model # ______________________________
      2. Total weight of PV Modules and Rails _______ lbs (Include total weight of hardware used along with module weight.)
      3. Total number of attachment points ___________ (Stagger attachment points so that all rafters carry some of the loads and certain rafters do not carry all panels.)

4. Weight per attachment point (#2 divided by #3) _______________lbs (If greater than 45 lbs, submit structural worksheet on page 14.)

45 lbs is a reasonable level below which point loading of roof joists and trusses can be ignored. Most standard mounting systems have point loadings of 25-35 lbs per attachment.

5. Maximum spacing between attachment points on a rail ________inches (See product manual for max spacing allowed based on wind loading. Spacing may be 48" O.C. at one wind speed and 60" O.C. at another.)
6. Total surface area of PV modules (square feet) ______________ ft^2 (Take the surface area of a single module and multiply by the total number of modules.)
7. Distributed weight of PV system of roof (#2 divided by #6) _________lbs/ft^2 (If distributed weight of the PV system is greater than 5 lbs/ft^2, submit Structural Worksheet on page 14.)

The 5 lbs/ft^2 limit is based on two things: 1) the roof is typical of standard code-compliant roof structures so that the structure either has the proper spans and spacing, or proper use of engineered trusses (first item under "Step 1: Structural Review of PV Array Mounting System"); and, 2) there is a single layer of roofing so that the normal weight allowance for additional roof layers is unused and available for the weight of the PV system. For applications on lightweight masonry roofing materials and other lightweight roofing products (e.g. metal, shake, etc.), these materials do not accept multiple layers and therefore the 5 lbs/ft^2 allowance is used to identify the maximum allowable additional weight for roofs that are exchanging the allowable live load for a dead load that prevents live load such as people walking on the roof.

Section 3

Step 2: Electrical Review of PV System (Calculations for Electrical Diagram)

1. In order for a PV system to be considered, the following must apply:
   a. PV modules (UL 1703), utility-interactive inverters (UL 1741), and combiner boxes (NEC 690.4 clearly listed and labeled for use with PV systems) are identified for use in PV systems.

   PV utility-interactive inverters must be specifically listed and labeled for this application [NEC 690.60 and 690.4] (Brackets refer to sections in the 2011 NEC throughout this document). Without this specific identification process, an unacceptable amount of review would be necessary to approve an inverter. Inverters that pass UL1741 and are listed as "utility-interactive" have met the requirement. Over 500 inverters currently meet this requirement. An inclusive list of these inverters is available online at: http://gosolarcalifornia.com/equipment/inverter.php. PV modules must also be listed and identified for use in PV systems [NEC 690.4]. PV modules that pass UL1703 and have a 600-Volt maximum voltage meet the requirement. A list of these modules is available online at http://gosolarcalifornia.com/equipment/pvmodule.php. Source circuit combiners must be listed and labeled to meet the DC voltage requirements of the PV system or be specifically tested for PV systems and clearly state the allowable maximum current and voltage [NEC 690.4].

   b. The PV array is composed of 4 series strings or less. For AC module and micro-inverter arrays, the PV array is composed of 4 branch circuits or less.

   The purpose of this requirement is to limit the number of options of what can comply as a "simple" system so that a single electrical diagram can be used to describe a large percentage of the systems being installed. The electrical diagram can handle up to 4 strings or branch circuits in parallel. This ensures that the conduit will have no more than eight current carrying conductors, which the ampacity tables in this guide have been based upon.

   c. The combined inverter continuous AC power output is 13,440 Watts or less.

The limit is set to stay generally within electrical interconnections that would be considered simple and possibly able to meet the 120% of busbar rating allowance in NEC 690.64(B) in a residence (minimum breaker for a 13.44 kWac PV system is 70 Amps at 240Vac). A 70-amp breaker is important since a 225-amp busbar in a 200-amp panel will allow a 70-amp PV breaker. Since this does happen from time to time, and an installer can choose to install such a panelboard, it is considered the largest "simple" PV system for purposes of this guideline. A table of breaker/ panelboard combinations is in Section 9 of this Guide, page 12.

d. The AC interconnection point is on the load side of service disconnecting means (NEC 690.64(B)).

Load side interconnections are by far the most common, particularly in residential applications. Any line side connection is covered by NEC 690.64(A) and 230.82. Although line side connections can be quite straightforward, they should require an additional step in the approval process and require a slightly different electrical drawing.

e. One of the standard electrical diagrams can be used to accurately represent the PV system:

1. Standard System (pages 16-17)
2. Micro-Inverter (pages 18-19)
3. AC Module (pages 20-21)
4. Supply-Side Connected (pages 22-23)

PV systems can vary significantly in PV array layout and inverter selection. However, the majority of small-scale, residential-sized PV systems can be accurately represented by these diagrams. These diagrams must be completely filled out in order for the permit package to be considered complete. These diagrams are not intended for use with battery-based systems. Interactive PDF versions of all the standard electrical diagrams can be found at www.solarabcs.org/permitting. These diagrams allow values to be input and the page to be saved and printed. You can also print and fill out the forms from this guide on pages 16-23.

Section 4
Inverter Information:

1. A copy of the manufacturer's specification sheet is required for a permit submittal. In addition, a printed out digital photo of the inverter listing label can be very helpful for gathering the ratings of the equipment.

a. Inverter Make

This is the manufacturer's name (e.g. Motech, PV Powered, SMA, etc.).

b. Inverter Model Number

This is the model number on the listing label (e.g. PVMate 3840U, PVP 5200, SB7000US, etc.).

c. Max DC Voltage Rating

Provided either on listing label or specification sheet

d. Max Power at 40ºC

The maximum continuous output power at 40ºC is required information for the listing. If the specification sheet does not clearly state the value, consult the manufacturer.

e. Nominal AC Voltage

This is the AC output voltage of the inverter as configured for this project. Some inverters can operate at multiple AC voltages.

f. Max OCPD Rating

This is the maximum overcurrent protective device (OCPD) rating allowed for the inverter. This is either stated on the listing label or in the installation manual. Sometimes this is also listed on the specification sheet—but not always. It is important to check that the inverter OCPD rating in the panel is less than or equal to this maximum rating to preserve the listing of the inverter.

Section 5
Module Information:

1. A copy of the manufacturer's specification sheet is required for a permit submittal. In addition, a printed out digital photo of the module listing label can be very helpful for gathering the ratings of the equipment. A prerequisite for a code-approved installation is the use of PV modules listed UL 1703 [NEC 690.4]. For a current list of modules that are listed to UL 1703, visit the *Go Solar California* website, *http://gosolarcalifornia.com/equipment/pvmodule.php*.

This module information is particularly important since it is used to calculate several current and voltage parameters required by the National Electrical Code (NEC). Listing information is necessary for NEC testing requirements [NEC 90.7, 100, 110.3, 690.4].

a. Module Manufacturer

This is the manufacturer's name (e.g. BP Solar, Evergreen, Solar World, Sharp, SunPower, Suntech etc.)

b. Module Model Number

This is the model number on the listing label (e.g. BP175B, EGS185, SW175 Mono, ND-U230C1, SP225, STP175S, etc.)

c. Max Power-Point Current (I_{MP})

The rated I_{MP} is needed to calculate system operating current. This is the current of the module when operating at STC and maximum power.

d. Max Power-Point Voltage (V_{MP})

The rated V_{MP} is needed to calculate system operating voltage. This is the voltage of the module when operating at Standard Test Conditions (STC) and maximum power.

e. Open-Circuit Voltage ($V_{OC)}$

The rated V_{OC} is needed to calculate maximum system voltage specified in NEC 690.7.

f. Short-Circuit Current (I_{SC})

The rated I_{SC} is needed to calculate maximum current specified in NEC 690.8(A).

g. Max Series Fuse (OCPD)

The maximum series fuse (OCPD) rating is needed to ensure that the proper overcurrent protection is provided for the modules and array wiring.

h. Max Power (P_{MAX}) at Standard Test Conditions (STC is 1000W/m2, 25°C cell temp, & Air Mass 1.5)

Maximum power at STC specifies the rated power of the PV module under simulated conditions.

i. Max System Voltage

Maximum system voltage (often but not always 600 V_{DC}) is needed to show that the NEC 690.7 voltage does not exceed this value.

Section 6
Array Information

1. This section defines the configuration of the PV array. PV arrays are generally made up of several modules in series, called "source circuits." These source circuits are often paralleled with multiple other source circuits to make up the entire DC generating unit called an "array." The last four items related to the PV array must be calculated and posted on a sign at the PV power source disconnect. The first two items a. and b. (Module Manufacturer and Module Model Number) characterize the array design and provide the information necessary to calculate the four items needed to produce proper array identification for the PV power source sign discussed in Section 7 that is required at the site.

a. Number of Modules in Series

For simplicity, this diagram only addresses the most common configuration of PV modules—multiple modules in series. Although single module PV power sources exist, it is more common to see PV arrays configured with as many as 12 to 24 modules in series.

b. Number of Parallel Circuits

Since single-phase inverters can be as large as 12 kW or more, and the largest PV source circuits are only about 2 to 5 kW, it is common for PV arrays to have two or more source circuits in parallel.

Example:
Number of modules in series = 14
Number of parallel source circuits = 3
Total number of modules = 14 x 3 = 42

c. Lowest Expected Ambient Temperature

Up through the 2008 edition, the NEC has not clearly defined "lowest expected ambient temperature." ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers) has performed statistical analysis on weather data from the National Weather Service. These data include values for the mean extreme temperatures for the locations with temperature data. The mean extreme low temperature is the coldest expected temperature for a location. Half of the years on record have not exceeded this number, and the rest have exceeded this number. These data are supplied in the appendix for reference. The 2011 NEC includes an informational Note to 690.7 that specifies the use of the ASHRAE mean extreme value for lowest expected ambient temperature when calculating maximum system voltage.

d. Highest Continuous Temperature (Ambient)

Up through the 2011 edition, the NEC has not clearly defined "highest continuous ambient temperature." Continuous is defined in the NEC as a 3-hour period Article 100. ASHRAE (American Society of Heating, Refrigeration, and Air Conditioning Engineers) has performed statistical analysis on weather data from the National Weather Service. These data include design values of 0.4%, 1%, and 2% for each month signifying that the temperature only exceeds the recorded value up to the specified time for a given location with temperature data. The average for June, July, and August of the 2% value has been chosen by the Copper Development Association as the value that best represents a condition that would create the 3-hour continuous condition referred to in Article 100. Two percent of one month is about 14 hours. Since high temperatures usually last for several days in most locations, the assumption is that at least one or two 3-hour high temperature events will happen during a given month. These data are supplied in the *appendix for reference. If a designer seeks a more conservative approach to temperature, the 0.4% data for hottest month of the year is an alternative value. 0.4% of one month is about 3 hours. Using the 0.4% value assumes that all 3 hours occur on the same day which would be the statistical worst case scenario. Both the 3-month average 2% data and the hottest single month 0.4% data are supplied in the appendix for reference.*

Section 7
Signs

1. PV Power Source
   a. Rated MPP (Max Power-Point) Current (sum of parallel source circuit operating currents)

Rated MPP current is found by multiplying the module rated MPP current for a module series string by the number of source circuits in parallel.

Example:
I_{MP} = 7.80 Amps
Number of source circuits in parallel = 3
7.80 Amps x 3 = 23.4 Amps

   b. Rated MPP (Max Power-Point) Voltage (sum of series modules operating voltage in source circuit)

Operating voltage is found by multiplying the module rated MPP voltage by the number of modules in a series source circuit.

Example:
V_{MP} = 29.5 Volts
Number of modules in series = 11
29.5 Volts x 11 = 325 Volts

   c. Max System Voltage [NEC 690.7]

Maximum system voltage is calculated by multiplying the value of V_{OC} on the listing label by the appropriate value on Table 690.7 in the NEC, and then multiplying that value by the number of modules in a series string. The table in the NEC is based on crystalline silicon modules and uses lowest expected ambient temperature at a site to derive the correction factor. Some modules do not have the same temperature characteristics as crystalline silicon so the manufacturer's instructions must be consulted to determine the proper way to correct voltage based on lowest expected ambient temperature. As of the 2008 NEC, the manufacturer's temperature correction factor must be used for all modules, regardless of construction, if the information is supplied. All known listed modules currently provide this information.

Table 690.7 Voltage Correction Factors

Lowest-Expected Ambient Temperature °C	°F	Temperature Correction Factor
0 to 4	32 to 40	1.10
-1 to -5	23 to 31	1.12
-6 to -10	14 to 22	1.14
-11 to -15	5 to 13	1.16
-16 to -20	4 to -4	1.18
-21 to -25	-5 to -13	1.20
-26 to -30	-14 to -22	1.21
-31 to -35	-23 to -31	1.23
-36 to -40	-32 to -40	1.25

Example:
Module V_{OC} = 37.0 Volts
Rating temperature= 25°C
Number of Modules in Series = 11
Lowest expected ambient temperature (ASHRAE)= 1°C (Ontario, California)

Maximum System Voltage = V_{MAX} = V_{OC} x # of Modules in Series x Temperature

Correction Factor
***Method 1**— Module Manufacturer's Temperature Correction Factor—Percentage Method*
Temperature Coefficient for V_{OC} = αV_{OC} = -0.37%/C = -0.0037/C
Temperature Correction Factor = 1 + α VOC (%) x ($Temp_{LOW}$ - $Temp_{RATING}$)
= 1 + (-0.0037/C) x (-1°C - 25°C)
= 1 + 0.0962 = 1.0962

V_{MAX} = 37V x 11 x 1.0962 = 446 Volts < 500Volts (compliant for a 500V_{MAX} inverter)

Method 2— Module Manufacturer's Temperature Correction Factor—Voltage Method
Temperature Coefficient for V_{OC} = αV_{OC} = 137mV/C = 0.137 V/C
Temperature Correction Factor = 1+[αV_{OC} (V) x ($Temp_{LOW}$ - $Temp_{RATED}$) ÷ V_{OC}]
= 1+ [0.137 V/C x (-1°C - 25°C) ÷ 37V]
= 1+ [5.206V ÷ 37V] = 1.0963

VMAX = 37V x 11 x 1.0963 = 446 Volts < 500Volts (compliant for a 500VMAX inverter)

Method 3—Table 690.7 Temperature Correction Factor
From row for ambient temperature = -1°C to -5°C 1.12

V_{MAX} = 37V x 11 x 1.12 = 456 Volts < 500Volts (compliant for a 500V_{MAX} inverter)

d. Max Circuit Current [NEC 690.8]

The maximum circuit current is calculated by multiplying the rated I_{SC} of the PV module by the number of source circuits operating in parallel, then multiplying this value by 125% to account for extended periods of sunlight above the tested solar intensity (rated irradiance=1000 W/m2; maximum continuous irradiance= 1250 W/m2). The NEC in 690.53 asks for the short-circuit current in the 2005 and 2008 editions, but the 2008 edition clarifies in a Fine Print Note that the intended value is the maximum circuit current as defined in 690.8 (A) and is a worst-case continuous short-circuit current value.

Example:
I_{SC} = 8.4 Amps
Number of source circuits in parallel = 3
8.4 Amps x 3 x 1.25 = 31.5 Amps

2. Warning Sign Required by NEC 690.17.

Any time a switch can have the load side energized in the open position, a warning sign must be placed on the switch. This is nearly always true of the dc disconnect at the inverter. The line side of the switch is energized by the PV array, while the load side of the switch is often energized by input capacitors of the inverter. These capacitors can remain energized for five minutes or more as the bleed resistors dissipate the charge over time. The warning sign should read essentially as follows:

WARNING: ELECTRICAL SHOCK HAZARD–LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION

3. Point of Connection Sign [NEC 690.54] (To be placed on the Solar AC Disconnect and AC Point of Connection locations)

a. AC Output Current

The AC output current, or rated AC output current as stated in the NEC, at the point of connection is the maximum current of the inverter output at full power. When the rated current is not specifically called out in the specification sheets, it can be calculated by taking the maximum power of the inverter, at 40°C, and dividing that value by the nominal voltage of the inverter.

Example:
Maximum Inverter Power = 7,000 watts
Nominal Voltage = 240 Volts
I_{RATED} *= 7,000 W/ 240 V = 29.2 Amps*

b. Nominal AC Voltage

The nominal AC voltage, or nominal operating AC voltage as stated in the NEC, at the point of connection is the nominal voltage (not maximum or minimum) of the inverter output. It will be the same as the service voltage. Most residential inverters operate at 240 Volts.

Example:
Nominal Voltage = 240 Volts

4. PV System Disconnect Location Directory [NEC 690.56(B)] (To be placed at service disconnect, if PV System disconnect is not located at the same location)

For first responders, it may not be readily apparent that a PV system has been installed on site. This directory indicates that a PV system has been installed on site and shows the disconnect location. This is only required if the PV disconnect is not immediately adjacent to the existing service disconnect.

Section 8
Wiring and Overcurrent Protection

1. DC Wiring Systems
   a. Source-circuit conductors:
      1. In Exposed Locations: PV module interconnections are generally 90°C wet-rated conductors NEC 690.31(A) FPN. The same conductor type is typically used for all home run conductors needed for source circuit conductors in exposed locations.
   b. Allowable wire types are as follows:
      1. USE-2 single conductor cable for exposed locations [NEC 690.31(B)].
      2. PV Wire or PV Cable as a single conductor for exposed locations (required for all ungrounded systems) [NEC 690.31(B), 690.3(0)(3)].

Typical temperature for PV modules in full sun at 20°C outdoor temperature is 50°C. This is a 30°C rise above outdoor temperatures. On the hottest day of the year, outdoor temperatures can reach a continuous temperature of 41°C in many hot locations throughout the United States. This means that the PV module could be operating at 71°C on the hottest day of the year (41°C+30°C =71°C). 75°C wire is insufficient for connection to a hot PV module under this condition. To further support the concern over the high temperature of PV modules, a fine print note has been added to the 2005 NEC.

"NEC 690.31 (A) FPN: Photovoltaic modules operate at elevated temperatures when exposed to high ambient temperatures and to bright sunlight. These temperatures may routinely exceed 70°C (158°F) in many locations. Module interconnection conductors are available with insulation rated for wet locations and a temperature rating of 90°C (194°F) or greater."

2. In Conduit on Rooftops:

a. Three options for source circuit conductor type (inside conduit choose one) THWN-2, XHHW-2 and RHW-2

Conductors in conduit, when exposed to direct sunlight, must account for the higher temperatures caused by intense sunlight and the proximity of the roof. The 2005 NEC first recognized the issue of sunlit conduit in a fine print note in NEC 310.10.

"310.10 FPN No. 2: Conductors installed in conduit exposed to direct sunlight in close proximity to rooftops have been shown, under certain conditions, to experience a temperature rise of 17°C (30°F) above ambient temperature on which the ampacity is based."

The 2008 NEC codified this issue by classifying the temperatures based on the height above the roof surface. On residential roofs, where conduit typically is spaced between ½" and 3 ½" above the roof surface, the temperature adder is stated as 22°C above the ambient temperature according to NEC Table 310.15(B)(2)(c): in the 2008 NEC, and Table 310.15 (B)(3)(c) in the 2011 NEC. Using this adder, along with the ASHRAE 2% design data for the hottest location in the U.S. (Palm Springs, CA is 44°C), produces a design temperature of 66°C and correction factor of 0.58 for 90°C conductors based on NEC Table 690.31 and Table 310.16 in the 2008 NEC, and 310.15(B)(16) in the 2011 NEC. If nine conductors or less are in the exposed conduit (4 pairs of conductors or less), then the conduit fill correction factor is 0.7 according to NEC Table 310.15(B)(2)(a): in the 2008 NEC, and Table 310.15(B) (3)(a) in the 2011 NEC. Putting all these correction factors together means that the 30°C conductor ampacity can be calculated as follows:

If only two strings in parallel (no fuses):

$\boldsymbol{I_{30^\circ C} = I_{MAX}/0.58/0.7 = 2.46 \times I_{MAX}}$

When I_{SC} *= 12.8 Amps or less, then* $I_{MAX} = I_{SC} \times 1.25$ *= 16 Amps or less.*

When I_{MAX} *= 16 Amps, then* $I_{30^\circ C}$ *= 39.4 Amps (10 AWG, 90°C required (NEC Table 310.16))*

When I_{SC}*= 9.6 Amps or less, then* $I_{MAX} = I_{SC} \times 1.25$ *= 12 Amps or less.*

When I_{MAX} *= 12 Amps, then* $I_{30^\circ C}$ *= 29.5 Amps (12 AWG, 90°C required (NEC Table 310.16))*

When I_{SC} *= 6.4 Amps or less, then* $I_{MAX} = I_{SC} \times 1.25$ *= 8 Amps or less.*

When I_{MAX} *= 8 Amps, then* $I_{30^\circ C}$ *= 19.7 Amps (14 AWG, 90°C required (NEC Table 310.16))*

If fuses are needed to protect PV modules (most cases), a shortcut to choose a conductor of sufficient ampacity is to use the following calculation:

$\boldsymbol{I_{30^\circ C} = I_{FUSE}/0.58/0.7 = 2.46 \times I_{FUSE}}$

When I_{SC} *= 6.4 Amps or less, then* $I_{MAX} = I_{SC} \times 1.25$ *= 8 Amps. The minimum overcurrent protective device (OCPD) as required by 690.8(B) is 10 Amps (*$I_{FUSE} = I_{MAX} \times 1.25$ *= 10A).*

When I_{FUSE} *= 10 Amps, then* $I_{30^\circ C}$ *= 2.46 x 10A = 24.6 Amps (14 AWG, 90°C required (NEC Table 310.16) -10A fuse to protect the conductor).*

When I_{SC} *= 7.68 Amps or less, then* $I_{MAX} = I_{SC} \times 1.25$ *= 9.6 Amps. The minimum overcurrent protective device (OCPD) as required by NEC 690.8(B) is 12 Amps (*$I_{FUSE} = {}_{IMAX} \times 1.25$ *=12A).*

When I_{FUSE} *= 12 Amps, then* $I_{30^\circ C}$ *= 2.46 x 12A = 29.5 Amps (12 AWG, 90°C required (NEC Table 310.16) -12A fuse to protect the conductor).*

When I_{SC} = 9.6 Amps or less, then I_{MAX} = I_{SC} x 1.25 = 12 Amps. The minimum overcurrent protective device (OCPD) as required by 690.8(B) is 15 Amps (I_{FUSE} = I_{MAX} x 1.25 = 15A).

When I_{FUSE} = 15 Amps, then $I_{30^{\circ}C}$. = 2.46 x 15A = 36.9 Amps (10 AWG, 90°C required (NEC Table 310.16) -15A fuse to protect the conductor).

When I_{SC} = 12.8 Amps or less, then I_{MAX} = I_{SC} x 1.25 = 16 Amps. The minimum overcurrent protective device (OCPD) as required by 690.8(B) is 20 Amps (I_{FUSE} = I_{MAX} x 1.25 = 20A).

When I_{FUSE} = 20 Amps, then $I_{30^{\circ}C}$. = 2.46 x 15A = 49.2 Amps (8 AWG, 90°C required (NEC Table 310.16) -20A fuse to protect the conductor). However, the NEC in 240.4(B) allows a conductor with an ampacity that falls between two standard OCPD sizes to be rounded up to the next higher OCPD size. Since a 10 AWG conductor has an ampacity of 16.24A after conditions of use are applied (I10AWG = 40A x 0.58 x 0.7 = 16.24), it is acceptable to protect a 10 AWG conductor with a 20A fuse according to NEC 240.4(B).

Since the highest I_{SC} module commonly available as of the writing of this guide is less than 12.8 Amps, 10 AWG conductors will always work regardless of location as long as there are no more than 9 current carrying conductors in the conduit and the conduit is at least 0.5" above the roof surface. Smaller wire can be used according to the I_{SC} of the modules being used and the number of conductors in the conduit. These calculations are provided so that contractors and jurisdictions will not need to repeat these standard calculations over and over.

The following table (Conductor Sizing Chart) summarizes the minimum wire size and overcurrent devices for circuits with overcurrent devices from 10 Amps up to 400 Amps in the hottest U.S. location. Wire size is adjusted for number of conductors in the raceway and is listed as minimum in case size needs to be increased to account for voltage drop on long circuits.

Conductor Sizing Chart for Hottest U.S. Climate						
For Sunlit Raceway 0.5"-3.5" from Roof and Max 2% Design Temp - 47°C						
80% Duty Fuses		100% Duty Fuses		Minimum Conductor Size in Raceway		
Fuse Size	Max Rated ISC	Fuse Size	Max Rated ISC	Based on # of Cond. in Raceway (AWG)		
Amps	Amps	Amps	Amps	8 conductors	4-6 cond.	2 cond.
10	6.4	10	8	14	14	14
12	7.68	12	9.6	12	14	14
15	9.6	15	12	10	10	14
20	12.8	20	16	10	10	12
25	16	25	20	8	8	10
30	19.2	30	24	6	8	8
35	22.4	35	28	6	68	
40	25.6	40	32	4	4	6
45	28.8	45	36	3	4	6
50	32	50	40	2	3	4
60	38.4	60	48	2	3	4
70	44.8	70	56	1	2	3
80	51.2	80	64	2/O	1/O	2
90	57.6	90	72	3/O	2/O	1
100	64	100	80	3/O	2/O	1/O
110	70.4	110	88	4/O	3/O	2/O
125	80	125	100	250MCM	4/O	2/O
150	96	150	120	300MCM	250MCM	3/O
175	112	175	140	400MCM	350MCM	4/O
200	128	200	160	2-3/O	400MCM	300MCM
225	144	225	180	2-4/O	500MCM	350MCM
250	160	250	200	2-250MCM	2-4/O	500MCM
300	192	300	240	2-300MCM	2-250MCM	600MCM
350	224	350	280	2-400MCM	2-350MCM	700MCM
400	256	400	320	2-500MCM	2-400MCM	1000MCM

b. AC Wiring Systems

Inverter Output Circuit overcurrent protection should be sized and protected according the manufacturer's directions. The circuit and corresponding overcurrent protection should be sized at a 125% of the maximum continuous output of the inverter [NEC 215.3 Overcurrent for Feeder Circuits, and NEC 690.8(A)(3) and 690.8(B)]. The 125 % increase over the maximum Inverter Output Circuit current is to account for the standard listing of overcurrent devices to 80% of maximum circuit current for continuous duty. Listed inverters have a maximum allowable overcurrent protection device requirement that is printed on the listing label or found in the installation manual.

For instance, a fictitious inverter, for example an AI-7000, has a maximum continuous output of 29.2 Amps and a maximum allowable overcurrent protection of 50 Amps. This means that the minimum allowable overcurrent is 40 Amps (29.2 Amps x 1.25 = 36.5Amps—round up to the next standard size, which is 40 Amps) and a maximum of 50 Amps. Normally, the minimum allowable breaker size is used since the panelboard supply breakers are constrained to 120% of the panelboard busbar rating.

Example:

Inverter continuous output rating = 7000 Watts

Nominal inverter voltage = 240 Volts

Maximum operating current = 7000 Watts / 240 Volts = 29.2 Amps

Min. Inverter Output Circuit ampacity = 29.2 Amps x 1.25 = 36.5 Amps

<u>Section 9</u>
AC Point of Connection

NEC 705.12 (D) in the 2011 NEC and 690.64 (B) in the 2008 NEC covers the requirements for Point of Connection of the PV inverter to the building electrical system. The most common method of connection is through a dedicated circuit breaker to a panelboard busbar. The sum of the supply breakers feeding the busbar of a panel can be up to 120% of the busbar rating.

A service panel containing a 200-amp busbar and a 200-amp main breaker will allow breakers totaling 120% of the busbar rating (240-Amps). Since the main breaker is 200 Amps, the PV breaker can be up to 40 Amps without exceeding the 120% allowance. For a service panel with a 125-amp busbar and a 100-amp main breaker, this provision will allow up to a 50 amp breaker (125 Amps x 1.2 = 150 Amps; 150 Amps - 100 amp main breaker = 50 Amp PV breaker).

A provision in the 2005 NEC clarifies the fact that dedicated circuit breakers backfed from listed utility-interactive inverters do not need to be individually clamped to the panelboard busbars. This has always been the case, but many inspectors have employed the provisions of NEC 408.36(F) that the breaker be secured in place by an additional fastener. Utility-interactive inverters do not require this fastener since they are designed to shut down immediately should the dedicated breaker become disconnected from the busbar under any condition. This provision is repeated in the 2008 NEC in a clear and concise statement:

"NEC 690.64(B)(6) Fastening. Listed plug-in-type circuit breakers backfed from utility-interactive inverters complying with 690.60 shall be permitted to omit the additional fastener normally required by 408.36(D) for such applications."

Since 690.64(B) and 705.12(D) are nearly identical in the 2008 NEC, the 2011 NEC references 705.12(D) in 690.64(B) so that all utility-interactive inverter interconnections are covered in the same section. This will help consistency among other inverter-based technologies such as fuel cells, wind, and micro-turbines. The table below, or Table of NEC 690.64(B) AC Interconnection Options, shows the how the maximum current of the inverter (column 1) requires a minimum size OCPD (column 2), which requires a minimum size conductor (column 3), which requires a compatible busbar/main breaker combination in the panelboard (column 4). The way to understand column 4, Minimum Busbar/Main Breaker Combinations," is to look at the row that coincides with the particular breaker being selected (from column 2) and use any combination from column 4 found on that row or higher in the table. For instance, a 40-

Amp inverter breaker works with a 200/200 panel combination, but it also works with a 125/100 combination found on the row above. The 40-Amp breaker does not work on the 150/150 combination, since the largest breaker would be 30 Amps for the 150/150 combination. Conductor size is listed as minimum in case size needs to be increased to account for voltage drop on long circuits.

TABLE OF NEC 690.64(B) AC INTERCONNECTION OPTIONS

Maximum Inverter Current	Required Inverter OCPD Size	Minimum Conductor Size in Conduit	Minimum Busbar/Main Breaker Combinations (Busbar Amps/Main Amps)
64 Amps	80 Amps	4 AWG	400/400; 200/150
56 Amps	70 Amps	4 AWG	225/200; 250/225
48 Amps	60 Amps	6 AWG	300/300; 200/175
40 Amps	50 Amps	8 AWG	125/100; 150/125
36 Amps	45 Amps	8 AWG	225/225
32 Amps	40 Amps	8 AWG	200/200
24 Amps	30 Amps	10 AWG	150/150
16 Amps	20 Amps	12 AWG	100/100; 70/60
12 Amps	15 Amps	14 AWG	80/80

Section 10
Grounding

1. System Grounding

The NEC requires [NEC 690.41] that all systems operating above 50 volts have one conductor referenced to ground unless the system complies with the requirements of NEC 690.35 for ungrounded PV arrays. For most PV systems, this connection is made in the inverter during manufacture, not on site by the installer.

2. Equipment Grounding

The code also requires that all exposed non-current-carrying metal parts of module frames, equipment, and conductor enclosures be grounded regardless of system voltage [NEC 690.43]. The grounding of module frames has received significant attention in the last several years. Many jurisdictions, with a heightened concern over the issue, have dramatically restricted effective grounding options.

3. Sizing of Grounding Conductors
   a. Equipment grounding conductor (EGC) sizing [NEC 690.45]
      1. The size of the EGC is dependent on whether the system has ground fault protection (GFP) equipment or not. The provisions for GFP equipment are stated in NEC 690.5. Almost all inverters have GFP equipment integral to the inverter and require that the PV array be grounded at the inverter only.
         i. Systems with ground fault protection equipment
            Size equipment grounding conductor according to NEC Table 250.122
         ii. Systems without ground fault protection equipment
            The NEC requires that equipment grounding conductors for systems without GFP equipment be sized for twice the minimum ampacity of the circuit conductors [NEC 690.45].
   b. System grounding conductor sizing
      1. AC System
         i. Size grounding electrode conductor (GEC) according to NEC Table 250.66 (Normally the site already has the conductor and electrode installed for the AC building wiring.)
      2. DC System
         ii. Size grounding electrode conductor (GEC) according to NEC 250.166 (This results in a minimum size of 8 AWG. The maximum size of the GEC is dependent upon the type of

grounding electrode or the maximum size conductor in the dc system, whichever is smaller.)

Structure Worksheet

If array is roof mounted:

This section is for evaluating roof structural members that are site built. This includes rafter systems and site built trusses. Manufactured truss and roof joist systems, when installed with proper spacing, meet the roof structure requirements covered in item 2 below.

1. Roof construction: Rafters Trusses Other: ___________________________________
2. Describe site-built rafter and ceiling or site-built truss system.
   a. Rafter size: _____x_____
   b. Rafter spacing: _____ inches on center
   c. Max unsupported span: _____ feet ____ inches (horizontal measurement not measured at the roof pitch angle)
3. Describe the site-built ceiling joists or rafter ties height
   a. Height of ties in relation to top plate and ridge:
   b.

Hc over Hr	1/3	1/4	1/5	1/6	1/7.5 or less
Adjustment	.67	.76	.83	.90	1.00

Hc= Height of ceiling above top plate
Hr= Height of ridge above top plate
Multiply span in table by adjustment factor.

Are the rafters over-spanned? (See IRC Span Tables on pages 26-27.) YES ☐ NO ☐

4. If the roof system has:
   a. Over spanned rafters or trusses;
   b. the array is over 5lbs/ft^2 on any roof construction; or,
   c. the attachments with a dead load exceeding 45 pounds per attachment;

It is recommended that you provide one of the following:

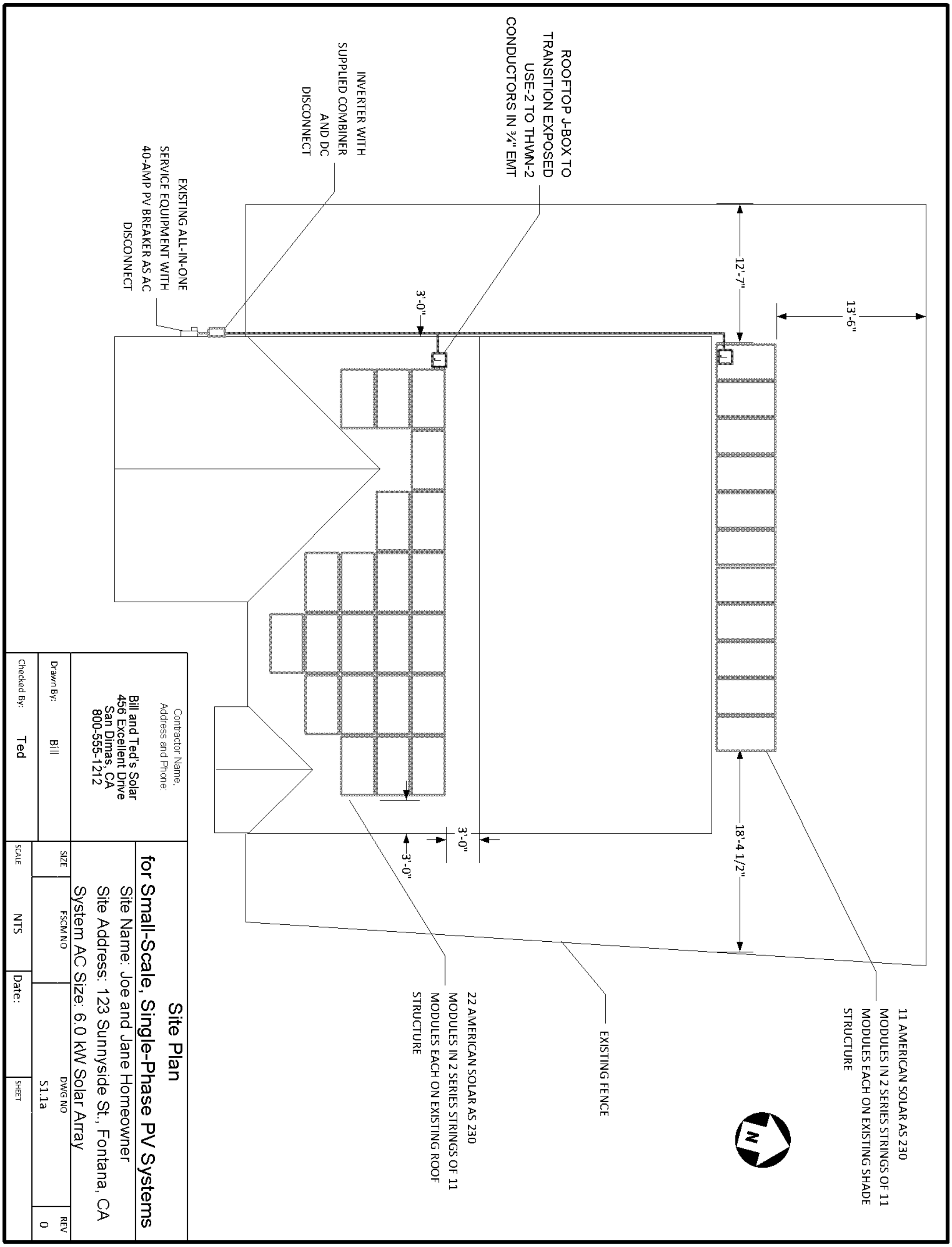
i. A framing plan that shows details for how you will strengthen the rafters using the supplied span tables in b.2.
ii. Confirmation certified by a design professional that the roof structure will support the array.

If array is ground mounted:

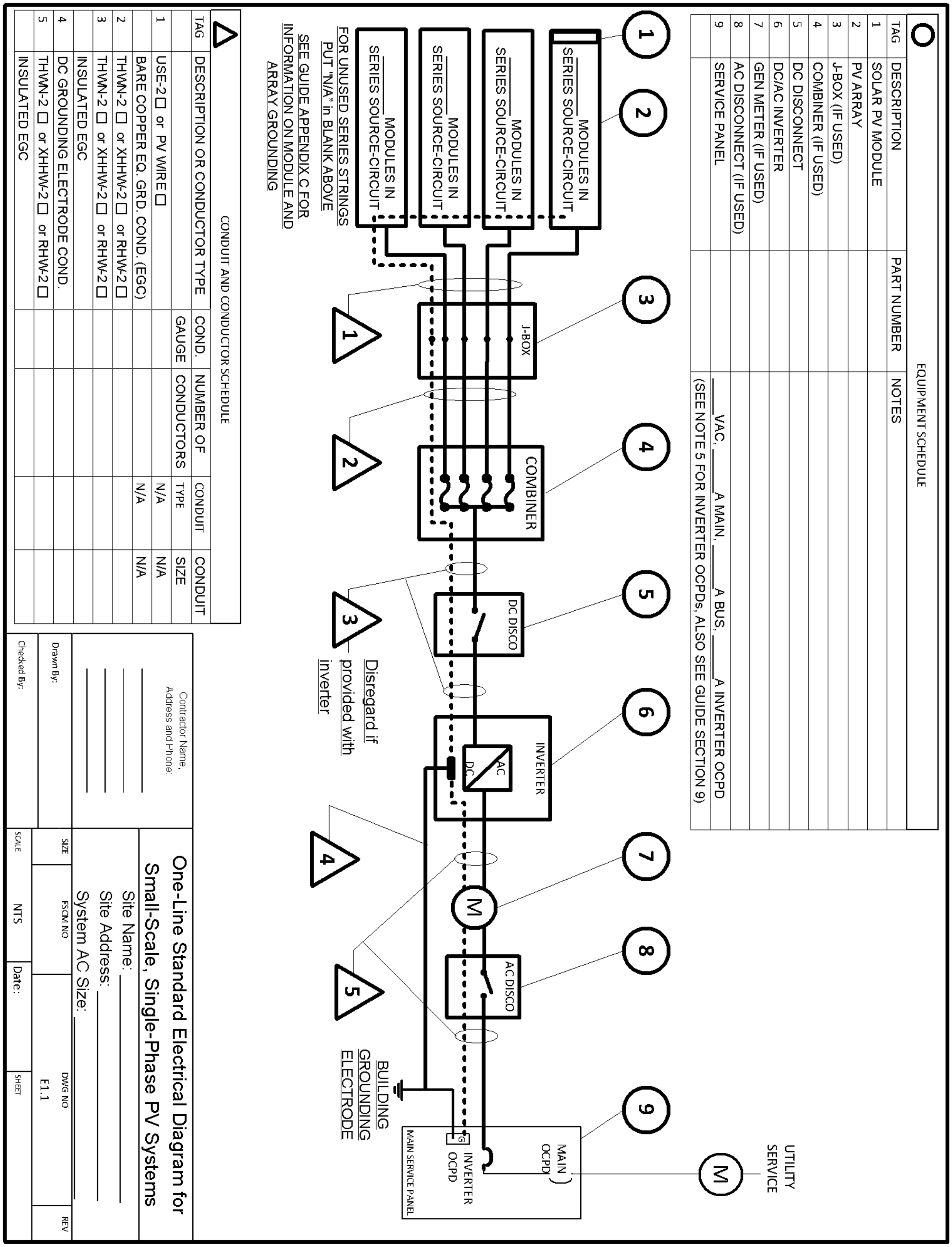
1. Show array supports, framing members, and foundation posts and footings.
2. Provide info on mounting structures construction. If the mounting structure is unfamiliar to the local jurisdiction and is more than 6’ above grade. It may require engineering calculations certified by a design professional.
3. Show detail on module attachment method to mounting structure.

Appendix

Example Site Plan



Standard Electrical Diagram



TAG	DESCRIPTION	PART NUMBER	NOTES
1	SOLAR PV MODULE		
2	PV ARRAY		
3	J-BOX (IF USED)		
4	COMBINER (IF USED)		
5	DC DISCONNECT		
6	DC/AC INVERTER		
7	GEN METER (IF USED)		
8	AC DISCONNECT (IF USED)		
9	SERVICE PANEL		____VAC, ____A MAIN, ____A BUS, ____A INVERTER OCPD (SEE NOTE 5 FOR INVERTER OCPDs, ALSO SEE GUIDE SECTION 9)

TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 ☐ or PV WIRE ☐			N/A	N/A
	BARE COPPER EQ. GRD. COND. (EGC)			N/A	N/A
2	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
	INSULATED EGC				
3	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
4	DC GROUNDING ELECTRODE COND.				
5	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
	INSULATED EGC				

Notes for Standard Electrical Diagram

NOTES FOR STANDARD ELECTRICAL DIAGRAM

PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE		
MODULE MODEL		
MAX POWER-POINT CURRENT (I_{MP})		A
MAX POWER-POINT VOLTAGE (V_{MP})		V
OPEN-CIRCUIT VOLTAGE (V_{OC})		V
SHORT-CIRCUIT CURRENT (I_{SC})		A
MAX SERIES FUSE (OCPD)		A
MAXIMUM POWER (P_{MAX})		W
MAX VOLTAGE (TYP 600V_{DC})		V
VOC TEMP COEFF (mV/°C ☐ or %/°C ☐)		
IF COEFF SUPPLIED, CIRCLE UNITS		

NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE

NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS *(NEC XXX.XX)*

INVERTER RATINGS (Guide Section 4)

INVERTER MAKE		
INVERTER MODEL		
MAX DC VOLT RATING		V
MAX POWER @ 40°C		W
NOMINAL AC VOLTAGE		V
MAX AC CURRENT		A
MAX OCPD RATING		A

SIGNS–SEE GUIDE SECTION 7

SIGN FOR DC DISCONNECT

PHOTOVOLTAIC POWER SOURCE		
RATED MPP CURRENT		A
RATED MPP VOLTAGE		V
MAX SYSTEM VOLTAGE		V
MAX CIRCUIT CURRENT		A
WARNING: ELECTRICAL SHOCK HAZARD–LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION		

SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM AC POINT OF CONNECTION		
AC OUTPUT CURRENT		A
NOMINAL AC VOLTAGE		V
THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)		

NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix D):

1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP ______°C

2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE _____°C

2.) 2005 ASHRAE FUNDEMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES),

a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.

b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT

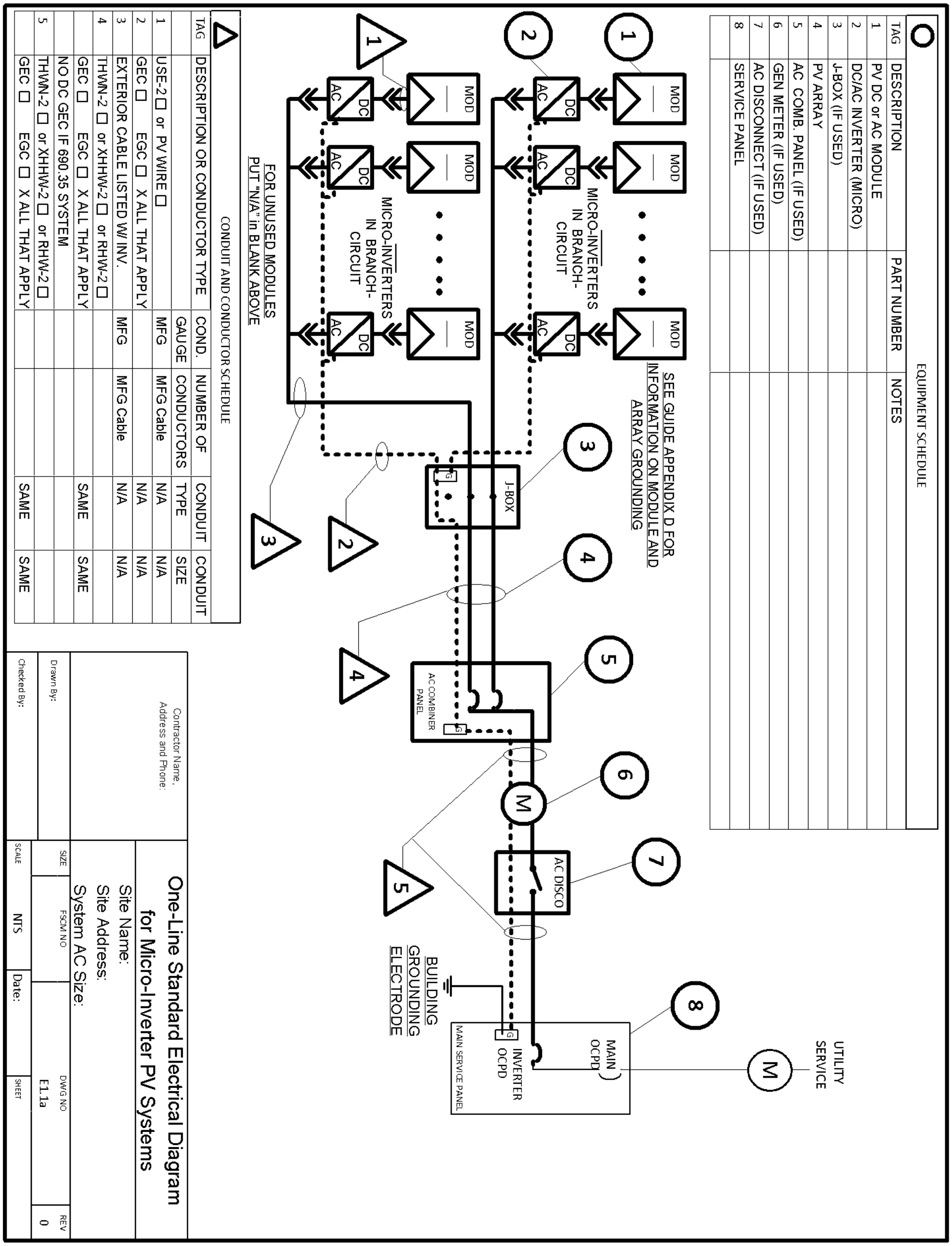
4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)

5) TOTAL OF ______ INVERTER OCPD(s), ONE FOR EACH INVERTER. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES ☐ NO ☐

Contractor Name, Address and Phone: ______ ______ ______ ______	Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems				
	Site Name: ______ Site Address: ______ System AC Size: ______				
Drawn By:	SIZE	FSCM NO	DWG NO E1.2		REV
Checked By:	SCALE NTS		Date:	SHEET	

Micro-Inverter Electrical Diagram

Micro-Inverter Electrical Diagram



Notes for Micro-Inverter Electrical Diagram

NOTES FOR MICRO-INVERTER ELECTRICAL DIAGRAM

PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE	
MODULE MODEL	
MAX POWER-POINT CURRENT (I_{MP})	
MAX POWER-POINT VOLTAGE (V_{MP})	
OPEN-CIRCUIT VOLTAGE (V_{OC})	
SHORT-CIRCUIT CURRENT (I_{SC})	
MAX SERIES FUSE (OCPD)	
MAXIMUM POWER (P_{MAX})	
MAX VOLTAGE (TYP 600V_{DC})	
VOC TEMP COEFF (mV/°C ☐ or %/°C ☐)	
IF COEFF SUPPLIED, CIRCLE UNITS	

NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE

NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS *(NEC XXX.XX)*

INVERTER RATINGS (Guide Section 4)

INVERTER MAKE	
INVERTER MODEL	
MAX DC VOLT RATING	
MAX POWER @ 40°C	
NOMINAL AC VOLTAGE	
MAX AC CURRENT	
MAX OCPD RATING	

SIGNS–SEE GUIDE SECTION 7

SIGN FOR DC DISCONNECT

No sign necessary since 690.51 marking on PV module covers needed information

SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM
AC POINT OF CONNECTION

AC OUTPUT CURRENT	
NOMINAL AC VOLTAGE	

THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)

NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix E):

1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP ____°C

2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE ____°C

2.) 2009 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES),

a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.
b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT

4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)

5) TOTAL OF ______ INVERTER OUTPUT CIRCUIT OCPD(s), ONE FOR EACH MICRO-INVERTER CIRCUIT. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES ☐ NO ☐

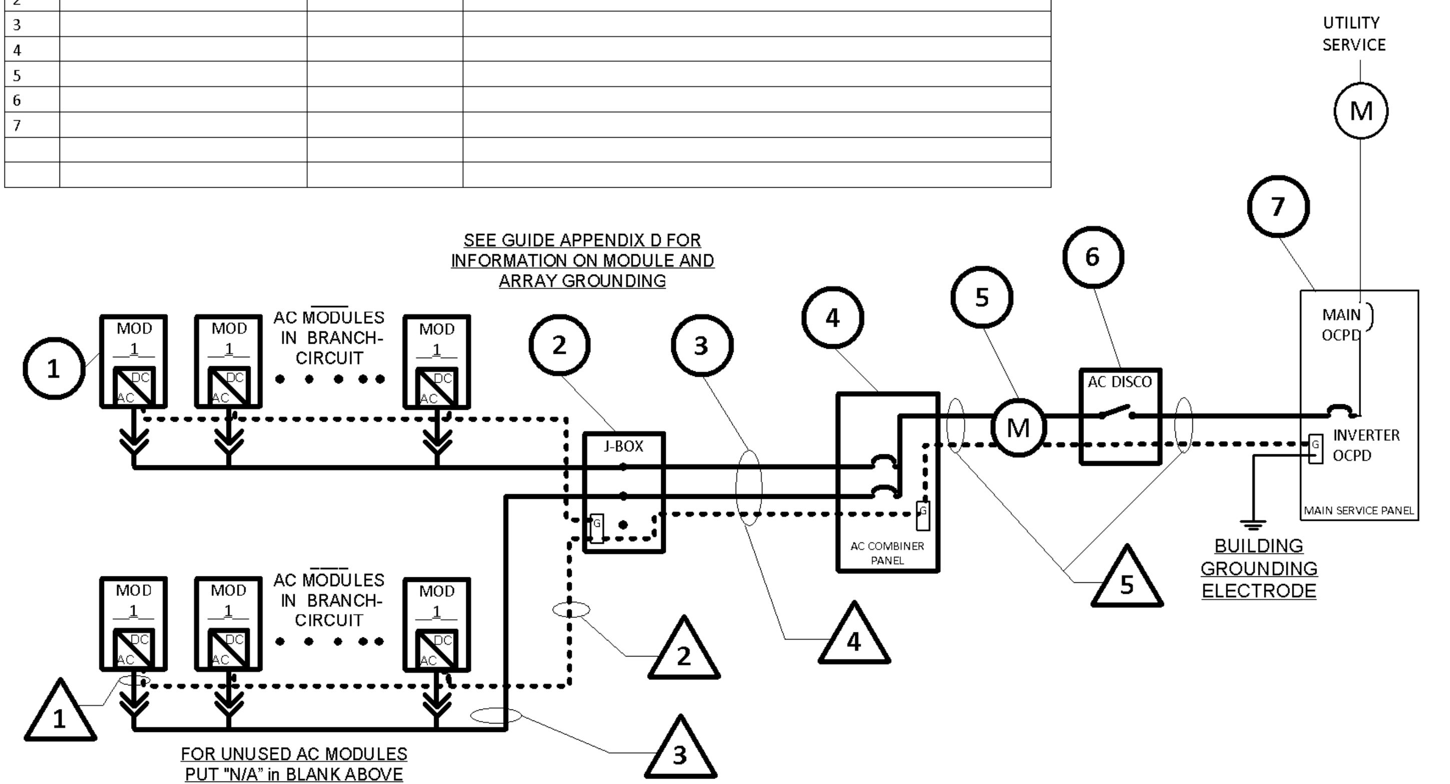
Contractor Name, Address and Phone:	Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems Site Name: Site Address: System AC Size:				
Drawn By:	SIZE	FSCM NO	DWG NO E1.2a		REV
Checked By:	SCALE NTS		Date:	SHEET	

AC Module Electrical Diagram

AC Module Electrical Diagram

EQUIPMENT SCHEDULE

TAG	DESCRIPTION	PART NUMBER	NOTES
1			
2			
3			
4			
5			
6			
7			



CONDUIT AND CONDUCTOR SCHEDULE

TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 ☐ or PV WIRE ☐	MFG	MFG Cable	N/A	N/A
2	GEC ☐ EGC ☐ X ALL THAT APPLY			N/A	N/A
3	EXTERIOR CABLE LISTED W/ INV.	MFG	MFG Cable	N/A	N/A
4	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
	GEC ☐ EGC ☐ X ALL THAT APPLY				
	NO DC GEC IF 690.35 SYSTEM				
5	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
	GEC ☐ EGC ☐ X ALL THAT APPLY				

Contractor Name, Address and Phone:

Drawn By:

Checked By:

One-Line Standard Electrical Diagram for AC Module PV Systems

Site Name:

Site Address:

System AC Size:

SIZE	FSCM NO	DWG NO	REV
		E1.1b	

SCALE	Date:	SHEET
NTS		

Notes for AC Module Electrical Diagram

Notes for AC Module Electrical Diagram

SIGNS–SEE GUIDE SECTION 7

SIGN FOR DC DISCONNECT

N/A since no dc wiring

SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM AC POINT OF CONNECTION	
AC OUTPUT CURRENT	
NOMINAL AC VOLTAGE	
THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)	

NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE

NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS *(NEC XXX.XX)*

AC MODULE RATINGS (Guide Appendix C)

AC MODULE MAKE	
AC MODULE MODEL	
NOMINAL OPERATING AC VOLTAGE	
NOMINAL OPERATING AC FREQUENCY	
MAXIMUM AC POWER	
MAXIMUM AC CURRENT	
MAXIMUM OCPD RATING	

NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix F):

1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP ____°C

2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE ___°C

2.) 2009 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR 6 OR LESS CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES),

a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR AC MODULES INVERTER OUTPUT CIRCUITS WITH 12 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER OCPD.

b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR AC MODULES INVERTER OUTPUT CIRCUITS WITH 16 AMPS OR LESS WHEN PROTECTED BY A 20-AMP OR SMALLER OCPD.

NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

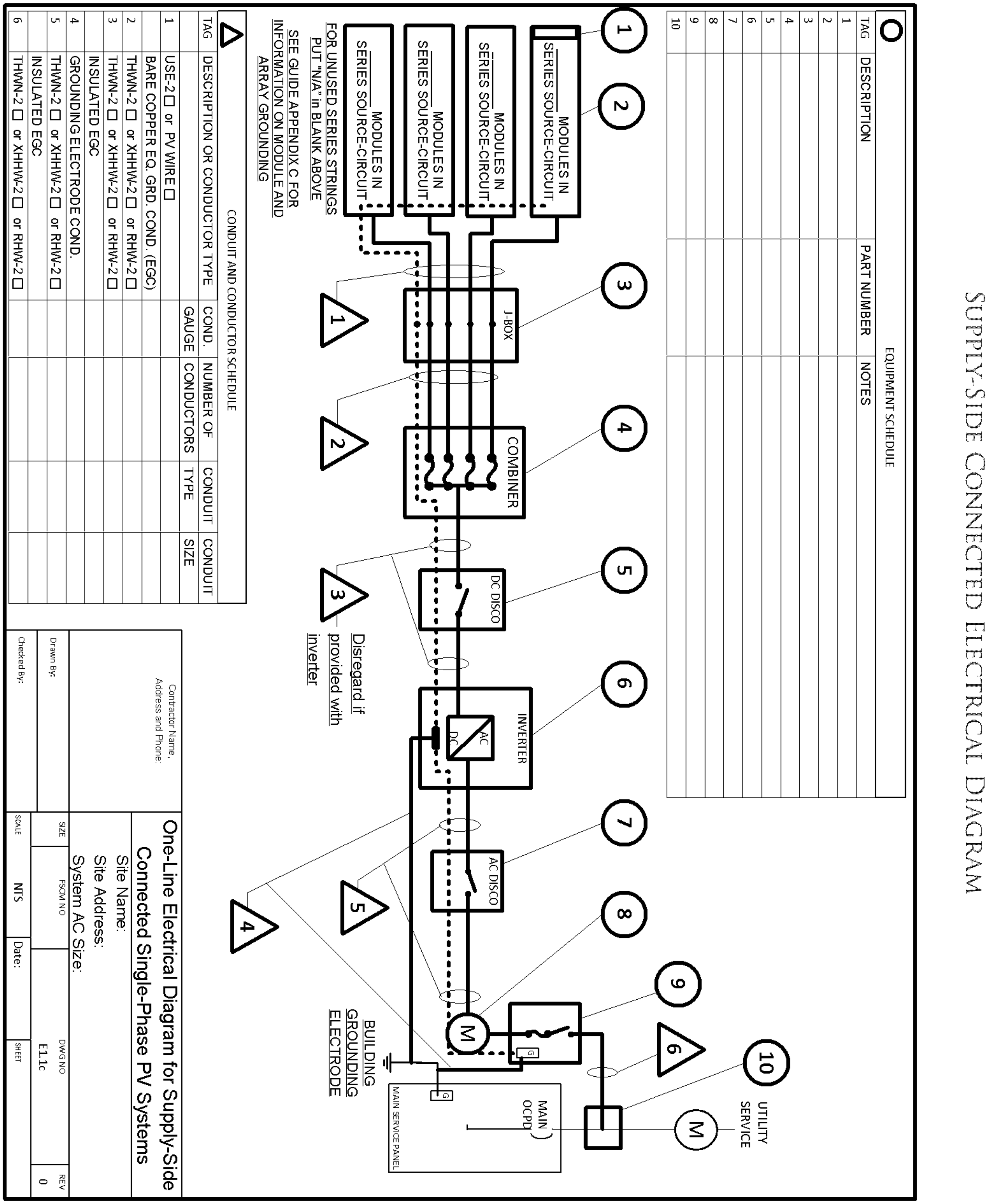
3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT (N/A)

4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)

5) TOTAL OF _____ INVERTER OUTPUT CIRCUIT OCPD(s), ONE FOR EACH AC MODULE CIRCUIT. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES☐ NO☐

Contractor Name, Address and Phone:	Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems Site Name: Site Address: System AC Size:
Drawn By: Bill	SIZE: / FSCM NO: / DWG NO: E1.2b / REV: 0
Checked By: Ted	SCALE: NTS / Date: / SHEET:

Supply-Side Connected Electrical Diagram



Notes for Supply-Side Connected Electrical Diagram

NOTES FOR SUPPLY-SIDE CONNECTED ELECTRICAL DIAGRAM

PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE	
MODULE MODEL	
MAX POWER-POINT CURRENT (I_{MP})	A
MAX POWER-POINT VOLTAGE (V_{MP})	V
OPEN-CIRCUIT VOLTAGE (V_{OC})	V
SHORT-CIRCUIT CURRENT (I_{SC})	A
MAX SERIES FUSE (OCPD)	A
MAXIMUM POWER (P_{MAX})	W
MAX VOLTAGE (TYP 600V_{DC})	V
VOC TEMP COEFF (mV/°C ☐ or %/°C ☐)	
IF COEFF SUPPLIED, CIRCLE UNITS	

NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE

NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS *(NEC XXX.XX)*

INVERTER RATINGS (Guide Section 4)

INVERTER MAKE	
INVERTER MODEL	
MAX DC VOLT RATING	V
MAX POWER @ 40°C	W
NOMINAL AC VOLTAGE	V
MAX AC CURRENT	A
MAX OCPD RATING	A

SIGNS–SEE GUIDE SECTION 7

SIGN FOR DC DISCONNECT

PHOTOVOLTAIC POWER SOURCE	
RATED MPP CURRENT	A
RATED MPP VOLTAGE	V
MAX SYSTEM VOLTAGE	V
MAX CIRCUIT CURRENT	A
WARNING: ELECTRICAL SHOCK HAZARD–LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION	

SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM AC POINT OF CONNECTION	
AC OUTPUT CURRENT	A
NOMINAL AC VOLTAGE	V
THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)	

NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix D):

1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP ______°C

2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE _____°C

2.) 2005 ASHRAE FUNDEMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES),

a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.
b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH Isc OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐

3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT

4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)

5) TOTAL OF ______ INVERTER OCPD(s), ONE FOR EACH INVERTER. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES ☐ NO ☐

Contractor Name, Address and Phone: ____ ____ ____ ____	Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems Site Name: ____ Site Address: ____ System AC Size: ____				
Drawn By:	SIZE	FSCM NO	DWG NO E1.2		REV
Checked By:	SCALE NTS		Date:	SHEET	

Appendix

Design Temperatures

The tables on the following pages indicate low and high ambient design temperatures that must be used when designing code-compliant PV systems. These temperatures have been provided by ASHRAE, and are given in degrees Celsius. The high temperatures are used for conductor sizing and calculations of minimum array operating voltage. The low temperatures are used in the NEC 690.7 calculation. This website provides an alternative method of viewing this same data: http://www.solarabcs.org/about/publications/reports/expedited-permit/map/index.html.

There are several numbers listed for each site. A description of each number follows:

1. Elev.: the elevation in meters of the meteorological site.
2. High Temp (0.4%): this air temperature is only exceeded during 3 hours (not necessarily continuous) of a summer month (June through August). This number is slightly more conservative than the 2% value.
3. High Temp (2%): this number is likely exceeded during 14 hours (not necessarily continuous) over a summer month (June through August). The Copper Development Association recommends that this number be used for ampacity calculations.
4. Distance above roof: The high temperature numbers refer only to the air temperature. According to the National Electrical Code, the temperature within rooftop raceways shall be assumed higher than ambient; these temperatures are dependent upon the minimum height of that conduit above the roof (NEC 2008 Table 310.15(B)(2)(c), or NEC 2011 Table 310.15(B)(3)(c)). The three figures here (0.5”, 3.5”, 12”) are based off the High Temp (2%) numbers. Conduit that touches the roof, or is less than 0.5” above the roof is not listed since it is poor practice to mount conduit this close to the roof in general.
5. Extreme Min: The lowest expected ambient temperature for this site. This number should be used for the calculations for maximum system voltage required in NEC 690.7. An Informational Note in 690.7(A) in the 2011 NEC specifies this value, the Extreme Annual Mean Minimum Design Dry Bulb Temperature from ASHRAE Handbook—Fundamentals, as the proper value for lowest expected ambient temperature.

ASHRAE Temperature Table

State	Station	Elev	High Temp (°C)		Distance above roof			Extreme
		(M)	0.4%	2% Avg	0.5"	3.5"	12"	Min (°C)
GA	BRUNSWICK MALCOLM MCKINNON AP	7	36	33	55	50	47	-5
GA	COLUMBUS METROPOLITAN ARPT	120	37	35	57	52	49	-9
GA	DEKALB PEACHTREE	313	36	34	56	51	48	-9
GA	DOBBINS AFB/MARIETT	330	36	34	56	51	48	-12
GA	FORT BENNING	88	38	36	58	53	50	-10
GA	FULTON CO ARPT BROW	263	36	34	56	51	48	-11
GA	GAINESVILLE\LEE GIL	389	35	33	55	50	47	-8
GA	HUNTER AAF	13	38	35	57	52	49	-5
GA	MACON MIDDLE GA REGIONAL AP	110	38	35	57	52	49	-9
GA	MOODY AFB/VALDOSTA	71	37	35	57	52	49	-7
GA	ROME R B RUSSELL AP	198	38	35	57	52	49	-11
GA	SAVANNAH INTL AP	16	37	35	57	52	49	-7
GA	VALDOSTA WB AIRPORT	60	37	35	57	52	49	-7
GA	WARNER ROBINS AFB	92	38	36	58	53	50	-8
GA	WAYCROSS WARE CO AP	43	38	35	57	52	49	-6
HI	BARBERS POINT NAS	10	34	32	54	49	46	13
HI	HILO INTERNATIONAL AP	11	30	29	51	46	43	15
HI	HONOLULU INTL ARPT	5	32	32	54	49	46	14
HI	KAHULUI AIRPORT	15	32	31	53	48	45	13
HI	KANEOHE BAY MCAS	6	30	29	51	46	43	16
HI	KONA INTL AT KEAHOL	15	31	30	52	47	44	14
HI	LIHUE AIRPORT	45	30	29	51	46	43	14
HI	MOLOKAI (AMOS)	137	31	30	52	47	44	13
IA	AMES MUNI ARPT	291	34	32	54	49	46	-26
IA	ANKENY REGIONAL ARP	275	37	34	56	51	48	-22
IA	ATLANTIC	360	36	33	55	50	47	N/A
IA	BOONE MUNI	354	35	33	55	50	47	N/A
IA	BURLINGTON MUNICIPAL AP	214	37	33	55	50	47	-23
IA	CARROLL	375	35	33	55	50	47	N/A
IA	CEDAR RAPIDS MUNICIPAL AP	266	36	33	55	50	47	-26
IA	CHARITON	320	37	33	55	50	47	-23
IA	CHARLES CITY	343	33	32	54	49	46	N/A
IA	CLARION	354	35	32	54	49	46	N/A
IA	CLINTON MUNI (AWOS)	216	35	32	54	49	46	-25
IA	CRESTON	394	36	33	55	50	47	-23
IA	DAVENPORT NEXRAD	259	34	32	54	49	46	-25
IA	DES MOINES INTL AP	294	37	33	55	50	47	-25
IA	DUBUQUE REGIONAL AP	329	34	31	53	48	45	-26
IA	ESTHERVILLE MUNI	401	34	31	53	48	45	-26
IA	FAIR FIELD	244	37	34	56	51	48	N/A
IA	FORT DODGE (AWOS)	355	35	32	54	49	46	-27
IA	KEOKUK MUNI	205	38	34	56	51	48	N/A
IA	MARSHALL TOWN MUNI	296	34	32	54	49	46	-26
IA	MASON CITY MUNICIPAL ARPT	373	35	32	54	49	46	-28
IA	OTTUMWA INDUSTRIAL AP	258	37	33	55	50	47	-24
IA	SIOUX CITY SIOUX GATEWAY AP	336	37	33	55	50	47	-26
IA	SPENCER	408	36	32	54	49	46	-28
IA	STORM LAKE	454	36	33	55	50	47	N/A
IA	WASHINGTON	230	36	33	55	50	47	N/A
IA	WATERLOO MUNICIPAL AP	268	36	33	55	50	47	-28
IA	WEBSTER CITY	342	35	33	55	50	47	-25
ID	BOISE AIR TERMINAL	874	39	36	58	53	50	-17
ID	BURLEY MUNICIPAL ARPT	1267	37	33	55	50	47	-20
ID	CALDWELL (AWOS)	740	39	35	57	52	49	-13
ID	CHALLIS	1546	36	32	54	49	46	-29
ID	COEUR D ALENE(AWOS)	707	36	32	54	49	46	-18
ID	ELK CITY (RAMOS)	1249	38	34	56	51	48	-15
ID	IDAHO FALLS FANNING FIELD	1448	36	33	55	50	47	-26
ID	JOSLIN FLD MAGIC VA	1297	38	34	56	51	48	-16
ID	LEWISTON NEZ PERCE CNTY AP	438	40	35	57	52	49	-14
ID	MCCALL ARPT	1530	33	29	51	46	43	-28
ID	MOUNTAIN HOME AFB	912	40	37	59	54	51	-19
ID	MULLAN (AWRS)	1011	32	30	52	47	44	-21
ID	POCATELLO REGIONAL AP	1365	37	34	56	51	48	-24
ID	SALMON/LEMHI (AWOS)	1233	36	31	53	48	45	-24
IL	AURORA MUNICIPAL	215	35	32	54	49	46	-25
IL	CAHOKIA/ST. LOUIS	126	37	34	56	51	48	-17
IL	CHICAGO MIDWAY AP	188	36	33	55	50	47	-22
IL	CHICAGO OHARE INTL AP	205	36	33	55	50	47	-24
IL	DECATUR	213	36	33	55	50	47	-22

Temperature Table Continued

State	Station	Elev (M)	High Temp (°C) 0.4%	High Temp (°C) 2% Avg	Distance above roof 0.5"	Distance above roof 3.5"	Distance above roof 12"	Extreme Min (°C)
IL	GLENVIEW NAS	199	36	33	55	50	47	-24
IL	LAWRENCEVILLE/VIN.	131	36	33	55	50	47	-18
IL	MARSEILLES ISLAND	225	36	33	55	50	47	-25
IL	MATTOON/CHARLESTON	220	35	32	54	49	46	-20
IL	MOLINE QUAD CITY INTL AP	181	37	34	56	51	48	-25
IL	MOUNT VERNON (AWOS)	146	36	34	56	51	48	-21
IL	PEORIA GREATER PEORIA AP	202	36	33	55	50	47	-23
IL	QUINCY MUNI BALDWIN FLD	234	37	33	55	50	47	-23
IL	ROCKFORD GREATER ROCKFORD AP	227	35	33	55	50	47	-26
IL	SCOTT AFB/BELLEVILL	135	37	35	57	52	49	-19
IL	SOUTHERN ILLINOIS	128	36	34	56	51	48	-17
IL	SPRINGFIELD CAPITAL AP	187	36	33	55	50	47	-23
IL	STERLING ROCKFALLS	197	35	32	54	49	46	-25
IL	UNIV OF ILLINOIS WI	236	36	33	55	50	47	-23
IL	W. CHICAGO/DU PAGE	231	35	32	54	49	46	-24
IN	EVANSVILLE REGIONAL AP	118	36	34	56	51	48	-19
IN	FORT WAYNE INTL AP	252	35	32	54	49	46	-23
IN	GRISSOM ARB	253	36	33	55	50	47	-23
IN	HUNTINGBURG	161	35	33	55	50	47	N/A
IN	INDIANAPOLIS INTL AP	246	35	32	54	49	46	-22
IN	LAFAYETTE PURDUE UNIV AP	194	36	33	55	50	47	-23
IN	MONROE CO	264	34	32	54	49	46	-21
IN	SOUTH BEND MICHIANA RGNL AP	236	36	32	54	49	46	-22
IN	TERRE HAUTE/HULMAN	175	36	33	55	50	47	-23
KS	CHANUTE MARTIN JOHNSON AP	308	38	35	57	52	49	-19
KS	COFFEYVILLE MUNI	230	38	36	58	53	50	-17
KS	CONCORDIA BLOSSER MUNI AP	452	40	37	59	54	51	-21
KS	DODGE CITY REGIONAL AP	790	40	37	59	54	51	-20
KS	ELKHART (AWOS)	1099	39	37	59	54	51	N/A
KS	FT RILEY/MARSHALL A	324	40	37	59	54	51	-20
KS	GARDEN CITY MUNICIPAL AP	878	39	37	59	54	51	-22
KS	GOODLAND RENNER FIELD	1124	39	36	58	53	50	-23
KS	GREAT BEND (AWOS)	575	41	37	59	54	51	-19
KS	HAYS MUNI (AWOS)	609	41	38	60	55	52	-20
KS	HILL CITY MUNICIPAL AP	677	42	38	60	55	52	-21
KS	LAWRENCE MUNI ARPT	254	39	36	58	53	50	-21
KS	LIBERAL MUNI	901	39	37	59	54	51	-18
KS	MANHATTAN RGNL	330	40	37	59	54	51	-22
KS	MCCONNELL AFB	414	40	37	59	54	51	-17
KS	MEDICINE LODGE ASOS	469	41	38	60	55	52	-17
KS	NEWTON (AWOS)	467	40	36	58	53	50	-17
KS	OLATHE/JOHNSON CO	334	37	35	57	52	49	-20
KS	PARSONS/TRI CITY	274	38	36	58	53	50	-19
KS	RUSSELL MUNICIPAL AP	568	41	37	59	54	51	-21
KS	SALINA MUNICIPAL AP	391	41	38	60	55	52	-20
KS	TOPEKA FORBES FIELD	329	38	35	57	52	49	-20
KS	TOPEKA MUNICIPAL AP	270	38	35	57	52	49	-21
KS	WICHITA MID-CONTINENT AP	408	41	37	59	54	51	-18
KS	WICHITA/COL. JABARA	433	41	36	50	50	50	-17
KS	WINFIELD/ARK CITY	353	40	37	59	54	51	-17
KY	BOWLING GREEN WARREN CO AP	164	36	33	55	50	47	-17
KY	CAPITAL CITY ARPT	245	35	32	54	49	46	-17
KY	CINCINNATI NORTHERN KY AP	269	36	32	54	49	46	-21
KY	FORT CAMPBELL (AAF)	173	37	34	56	51	48	-16
KY	FORT KNOX/GODMAN	239	37	33	55	50	47	-18
KY	HENDERSON CITY	117	35	33	55	50	47	-19
KY	JACKSON JULIAN CARROLL AP	414	34	31	53	48	45	-18
KY	LEXINGTON BLUEGRASS AP	301	35	33	55	50	47	-19
KY	LONDON-CORBIN AP	369	34	32	54	49	46	-18
KY	LOUISVILLE BOWMAN FIELD	170	37	34	56	51	48	-18
KY	LOUISVILLE STANDIFORD FIELD	149	36	34	56	51	48	-17
KY	PADUCAH BARKLEY REGIONAL AP	126	36	34	56	51	48	-17
KY	SOMERSET(AWOS)	283	37	34	56	51	48	-13
LA	ALEXANDRIA ESLER REGIONAL AP	36	38	35	57	52	49	-7
LA	ALEXANDRIA INTERNATIONAL	27	37	35	57	52	49	-7
LA	BARKSDALE AFB	54	38	35	57	52	49	-9
LA	BATON ROUGE RYAN ARPT	23	35	34	56	51	48	-6
LA	FORT POLK (ARMY)	102	37	35	57	52	49	-6
LA	GRAND ISLE	10	32	31	53	48	45	0
LA	LAFAYETTE REGIONAL AP	13	35	34	56	51	48	-6

Span Tables

A framing plan is required only if the combined weight of the PV array exceeds 5 pounds per square foot (PSF or lbs/ft2) or the existing rafters are over-spanned. The following span tables from the 2009 International Residential Code (IRC) can be used to determine if the rafters are over-spanned. For installations in jurisdictions using different span tables, follow the local tables.

Span Table R802.5.1(1)

Use this table for rafter spans that have conventional light-weight dead loads and do not have a ceiling attached.

10 PSF Dead Load Roof live load = 20 psf, ceiling not attached to rafters, L/Δ=180							
Rafter Size			2 x 4	2 x 6	2 x 8	2 x 10	2 x 12
Spacing (inches)	Species	Grade	The measurements below are in feet-inches (e.g. 9-10 = 9 feet, 10 inches).				
16	Douglas Fir-larch	#2 or better	9-10	14-4	18-2	22-3	25-9
16	Hem-fir	#2 or better	9-2	14-2	17-11	21-11	25-5
24	Douglas Fir-larch	#2 or better	8-0	11-9	14-10	18-2	21-0
24	Hem-fir	#2 or better	7-11	11-7	14-8	17-10	20-9

Use this table for rafter spans that have heavy dead loads and do not have a ceiling attached.

20 PSF Dead Load Roof live load = 20 psf, ceiling not attached to rafters, L/Δ=180							
Rafter Size			2 x 4	2 x 6	2 x 8	2 x 10	2 x 12
Spacing (inches)	Species	Grade	The measurements below are in feet-inches (e.g. 9-10 = 9 feet, 10 inches).				
16	Douglas Fir-larch	#2 or better	8-6	12-5	15-9	19-3	22-4
16	Hem-fir	#2 or better	8-5	12-3	15-6	18-11	22-0
24	Douglas Fir-larch	#2 or better	6-11	10-2	12-10	15-8	18-3
24	Hem-fir	#2 or better	6-10	10-0	12-8	15-6	17-11

Span Table R802.5.1(2)

Use this table for rafter spans with a ceiling attached and conventional light-weight dead loads.

10 PSF Dead Load Roof live load = 20 psf, ceiling attached to rafters, L/Δ=240							
		Rafter Size	2 x 4	2 x 6	2 x 8	2 x 10	2 x 12
Spacing (inches)	Species	Grade	The measurements below are in feet-inches (e.g. 9-10 = 9 feet, 10 inches).				
16	Douglas Fir-larch	#2 or better	8-11	14-1	18-2	22-3	25-9
16	Hem-fir	#2 or better	8-4	13-1	17-3	21-11	25-5
24	Douglas Fir-larch	#2 or better	7-10	11-9	14-10	18-2	21-0
24	Hem-fir	#2 or better	7-3	11-5	14-8	17-10	20-9

Use this table for rafter spans with a ceiling attached and where heavy dead loads exist.

20 PSF Dead Load Roof live load = 20 psf, ceiling attached to rafters, L/Δ=240							
		Rafter Size	2 x 4	2 x 6	2 x 8	2 x 10	2 x 12
Spacing (inches)	Species	Grade	The measurements below are in feet-inches (e.g. 9-10 = 9 feet, 10 inches).				
16	Douglas Fir-larch	#2 or better	8-6	12-5	15-9	19-3	22-4
16	Hem-fir	#2 or better	8-4	12-3	15-6	18-11	22-0
24	Douglas Fir-larch	#2 or better	6-11	10-2	12-10	15-8	18-3
24	Hem-fir	#2 or better	6-10	10-0	12-8	15-6	17-11

Use the conventional light-weight dead load table when the existing roofing materials are wood shake, wood shingle, composition shingle, or light-weight tile. (The rationale for allowing these tables to be used is that the installation of a PV system should be considered as part of the live load, since additional loading will not be added to the section of the roof where a PV array is installed.) Where heavy roofing systems exist (e.g. clay tile or heavy concrete tile roofs), use the 20 lbs/ft2 dead load tables.